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MSS. intended for publication and books, etc., intended for review should be sent to Professor J. McKeen Cattell, Garrison-on-Hudson, N. Y.

LIEBIG'S LAW OF THE MINIMUM IN RELATION TO GENERAL BIOLOGICAL PROBLEMS[1]

THE Law of the Minimum has never been accurately defined, although the idea that it involves is relatively simple. Professor B. E. Livingston says in a recent paper[2] that "this principle is still quite incomplete logically and its statement will assuredly become much more complex as our science advances." In order to get a clear understanding of the law so that it may be stated accurately, we will begin with a simple application to chemical reactions.

One molecule of KOH reacts with one molecule of HCl to form one molecule of KCl and one of H_2O. If only one molecule of KOH is present, only one molecule of KCl can be formed, no matter how many molecules of HCl are present; and likewise if only one molecule of HCl is present, only one molecule of KCl can be formed, no matter how many molecules of KOH are present. By considering the weights of the reacting substances, the situation is somewhat complicated: 56.1 grams of KOH react with 36.5 grams of HCl to form 74.6 grams of KCl and 18 grams of H_2O. In round numbers 3 parts by weight of KOH and two of HCl give 4 parts by weight of KCl and one of H_2O: 3/4 gr. of KOH and 1/2 gr. of HCl are necessary to form a gram of KCl. Let us call these fractions, 3/4 and 1/2, the specific reactive weights of KOH and HCl in respect to the formation of a unit quantity of KCl. Suppose x amount of KOH and y of HCl are given. If x and

[1] Paper read before the Biological Club of Yale University, April 19, 1917.

[2] *Plant World*, 20: 1–15, 1917.

y are divided by their respective specific reactive weights, we get $\frac{4}{3}x$ and $2y$. The smaller of these quantities is a direct measure of the weight of KCl that can be formed from x KOH and y HCl. If, for example, x and y are both equal to three grams, four grams of KCl can be obtained.

These facts can be generalized. If A, B and C are substances which react to form S and u A, v B and w C are necessary for the formation of a unit amount of S, then u, v and w may be called the specific reactive values of A, B and C, respectively. They may be weights, volumes, numbers of molecules or what not. In any particular case, where pA, qB and rC are reacting, the amount of S formed is the smallest of the fractions p/u, q/v, r/w. When the amounts of the reacting substances are divided by their specific reactive values, the smallest quantity so obtained is equal to the amount of the product formed.

This conclusion is directly applicable to the problem of fertilizers. It is known that most of the higher plants must obtain seven elements in combined form from the soil. They are S, P, N, K, Ca, Mg and Fe. If αS, βP, γN, δK, ϵCa, ζMg and ηFe are required for a unit amount of growth in some particular plant, say wheat, and if aS, bP, cN, dK, eCa, fMg and gFe are present in a particular soil in available form, the maximum amount of wheat that can be grown in that soil will be the smallest of the fractions a/α, b/β, c/γ, d/δ, e/ϵ, f/ζ, g/η. In this case α, β, γ, etc., may be called specific growth values for the plant under consideration. When the available amounts of the essential inorganic food constituents are divided by their respective growth values, the smallest quantity obtained gives the maximum amount of growth possible.

It was in this connection that Liebig[3] first formulated the Law of the Minimum which, as commonly stated,[4] says that "the yield of any crop always depends on that nutritive constituent which is present in minimum amount." The use of the term minimum is not strictly accurate, as can be seen from the example of KOH and HCl. If three grams of each are present, the amount of KOH determines the yield of KCl, although both HCl and KOH are present in equal amount. However, the above statement of the law is convenient because of its simplicity.

A much broader application of the Law of the Minimum was indicated by the work of F. F. Blackman, whose conclusions are summarized in his paper on "Optima and limiting factors."[5] Blackman called attention to the complexity of the process of carbon assimilation, the rate of which depends on at least six factors—

1. Temperature,
2. Light intensity,
3. Carbon-dioxide supply,
4. Water supply,
5. Chlorophyll,
6. Enzymes.

Where it is possible to vary one of these factors independently of the rest, its effect on the rate of assimilation can be measured, under suitable conditions, and a curve plotted. In this way a temperature-assimilation curve, a light-assimilation curve and a carbon-dioxide-assimilation curve can be constructed. The other factors are more difficult to control. The following curves were constructed by Blackman and Smith[6] from a study of the rate of assimilation in *Elodea*.

The light curve and the carbon-dioxide curve are straight lines. The rate of assimilation varies directly with the inten-

[3] "Die Chemie in ihre Anwendung auf Agricultur und Physiologie," 7te Auflage, 2: 225, 1862.

[4] *Cf.* F. Czapek, "Biochemie der Pflanzen," 2: 841, 1905.

[5] *Annals of Botany*, 19: 281–295, 1905.

[6] *Proc. R. Soc., B.*, 83: 389–412, 1910.

sity of light and the supply of carbon dioxide. The temperature curve shows that the rate of assimilation is an exponential function of the temperature. In fact the process of assimilation obeys van't Hoff's

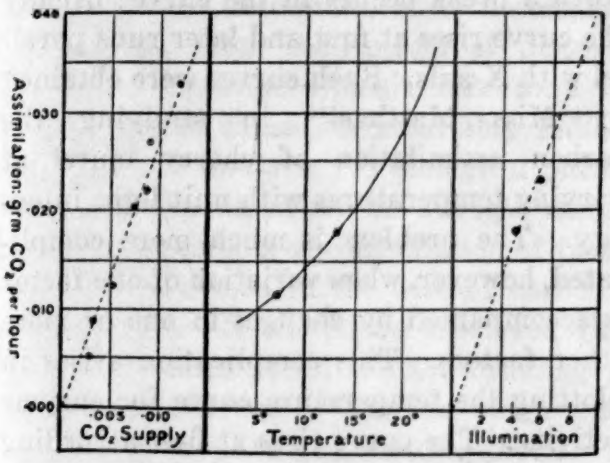

FIG. 1. Effect of external factors on assimilation in *Elodea*. (After Blackman and Smith.)

law of reactions for temperatures under 30° C. Above this, the rate of assimilation at first rises and then falls off, the process being complicated at high temperatures by a "time factor." The same effect has been observed at high light intensities, and with strong concentrations of carbon-dioxide which have a narcotic effect.

Disregarding these complications, we will confine our attention to the first parts of these curves. The ordinates of all three curves are the same, namely, rates of carbon assimilation, which can be measured in terms either of CO_2 absorbed or of sugar produced. The former happens to be the more convenient measure. At any given temperature, the rate of assimilation which is a function of that particular temperature can be determined directly by the curve and is equal to a certain distance measured off from the origin on the Y-axis. Similar distances are given for any definite supply of carbon dioxide and for any degree of illumination. In any actual environmental complex, where the temperature, light and carbon-dioxide supply are known, the rate of assimilation is equal to the shortest distance measured on the Y-axis. This is stated as a general principle by Blackman as follows: "When a process is conditioned as to its rapidity by a number of separate factors, the rate of the process is limited by the pace of the 'slowest' factor." The factor which gives the shortest distance on the Y-axis—that is, the "slowest" factor, he calls the limiting factor.

As a matter of fact the carbon assimilation of green plants is usually limited by the seasonal variation in temperature and the diurnal variation in light, the CO_2 content of the air being constant. Nothing has been said of the other factors that effect carbon assimilation—the water supply, chlorophyll and enzymes. These so-called "internal" factors, as well as the "external" factors, are governed by the Law of the Minimum. Of the internal factors, water and chlorophyll are present in excess in healthy green plants, the amount of assimilatory enzymes being the only probable limiting factor.

It is not necessary to adduce additional examples to show that the Law of the Minimum is a *universal* law, affecting not merely the concentration of reacting substances, but *all* factors that in any way influence a reaction or process. The law is applicable to physical, chemical and geological as well as biological problems.[7] An interesting instance of its application to a problem in physics is the determination of the magnitude of a thermionic current. This varies with changes in temperature, and also with changes in the voltage applied. The temperature formula gives one value, the voltage formula may give another; the lesser value determines the current flowing. The

[7] A timely application may be made which is worth bearing in mind. The efficiency of a nation at war is subject to the Law of the Minimum. Defeat, in the last analysis, may be attributed to the effect of some limiting factor.

application of the Law of the Minimum has been worked out in many cases and has been of great use in the interpretation of complicated relations; but it has been recognized as a law and has been consciously applied by plant physiologists and physiological chemists only.[8] Without doubt it can be used to advantage in many problems of the physiology, morphology and ecology of both plants and animals.

The Law of the Minimum must be taken into account in all experimental work, for which it serves both as a precaution and a guide.[9] When investigating the effect of an external factor such as temperature, light, etc., on any given process, it is necessary to keep all other variable factors constant, and then to determine the effect of changes in the factor under consideration. What results might be obtained when this method is used in studying carbon assimilation? Suppose the CO_2 supply and the light are kept constant, while the temperature is varied. If the CO_2 supply is such that it becomes a limiting factor when the temperature rises above 10° C. then the rate of assimilation will rise with the temperature up to this point, but will remain constant at all higher temperatures, until the destructive effect of the high temperature is manifested and the curve again falls off. Above 10° C. variations in the temperature have no apparent effect under these experimental conditions. But if the CO_2 supply is increased so as to permit more rapid assimilation, then the temperature curve can be extended. Negative results from such an experimental method are therefore without significance. It is not enough that the experiment be conducted under constant conditions; the constant factors must not interfere in any way with the carrying out of the process; that is, they must not be limiting factors. On the other hand, it is a simple matter to determine by the shape of the curve whether any other factor than the one under investigation is a limiting factor. Such is always the case when a break occurs in the curve; usually the curve rises at first and later runs parallel with X-axis. Such curves were obtained by Miss Matthaei[10] in studying the carbon assimilation of cherry laurel at varying temperatures with unit light intensity. The problem is much more complicated, however, when variation of one factor is accompanied by changes in one or more other factors. This complication arises in plotting the temperature curve for enzyme activity. The curve rises at first according to van't Hoff's law of reactions, but eventually a maximum value is reached and the curve falls off. At some point near the end of the ascending portion of the curve a

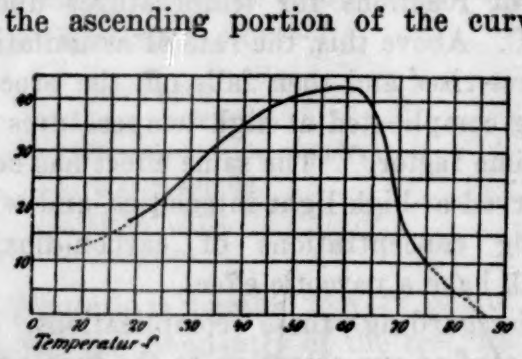

Fig. 2. Effect of temperature on the activity of malt diastase. (After Kjeldahl.)

break occurs: for all temperatures below this point, temperature is the limiting factor and determines the activity of the enzyme; for all temperatures above this point, not temperature, but the amount of enzyme is the limiting factor. The higher temperatures cause a permanent inactivation or decomposition of the enzyme so that its activity is conditioned only secondarily by the temperature. There is also a time factor involved here; the longer the temperature acts, the more the enzyme is decomposed, within certain limits. The study

[8] *Cf.* the work of L. B. Mendel, T. B. Osborne and their pupils.

[9] *Cf.* B. E. Livingston, *loc. cit.*

[10] *Phil. Trans.*, B, 196: 47–105, 1904.

of the action of salt solutions on permeability, growth, etc., involve even greater complications produced by the interrelation of conditioning factors.

In order to get an accurate statement of the Law of Minimum, it is necessary to get away from the custom of discussing causes, however difficult this may be.[11] The idea of causation invariably indicates *incomplete analysis*. A biological phenomenon is dependent not on a single variable, but on a complex or constellation of factors, as we have seen in the case of carbon assimilation. It should be discussed therefore in terms of all the conditioning factors, not in terms of that one which temporarily happens to be a limiting factor. The term "function" is valuable in this connection. The amount of carbon assimilation is a function of the temperature; it is another function of the illumination, etc. With this idea of function in mind, the Law of the Minimum may be stated in the following form. *When a quantity is dependent on a number of variable factors and must be a function of one of them, the quantity is that function which gives the minimum value.* Expressed in plain English this means that a chain is no stronger than its weakest link. The Law of the Minimum is only too obvious. Its application is often so self-evident that it is made as a matter of course.

But the most interesting thing about the law is not how it works, but when it does not work. There is a fundamental discrepancy between the Law of the Minimum and Galton's Law of averages. In the current text-books on genetics and plant physiology[12] the following ingenious explanation of Galton's Law is given. Assume that the size of a bean is determined by only five variables, each of which must occur in one of two categories; in one case the size of the bean will be increased by one unit of size, in the other it will be decreased by the same amount. Considering all the possible permutations of these five variables, we get the following arrangement:

I	II	III	IV	V	Sum	I	II	III	IV	V	Sum
+	+	+	+	+	+5	+	+	−	−	−	−1
+	+	+	+	−	+3	+	−	+	−	−	−1
+	+	+	−	+	+3	+	−	−	+	−	−1
+	+	−	+	+	+3	+	−	−	−	+	−1
+	−	+	+	+	+3	−	+	+	−	−	−1
−	+	+	+	+	+3	−	+	−	+	−	−1
+	+	+	−	−	+1	−	+	−	−	+	−1
+	+	−	+	−	+1	−	−	+	+	−	−1
+	+	−	−	+	+1	−	−	+	−	+	−1
+	−	+	+	−	+1	−	−	−	+	+	−1
+	−	+	−	+	+1	+	−	−	−	−	−3
+	−	−	+	+	+1	−	+	−	−	−	−3
−	+	+	+	−	+1	−	−	+	−	−	−3
−	+	+	−	+	+1	−	−	−	+	−	−3
−	+	−	+	+	+1	−	−	−	−	+	−3
−	−	+	+	+	+1	−	−	−	−	−	−5

The beans will be of six sizes, +5, +3, +1, −1, −3, −5, and out of a very large number (n), $n/32$ will be +5, $5n/32$ will be +3, $10n/32$ will be +1, $10n/32$ will be −1, $5n/32$ will be −3, and $n/32$ will be −5. The six sizes are in the ratio 1:5:10:10:5:1. If we plot the sizes of the various classes of beans against the frequency of their occurrence, we get an approximation to the familiar curve of normal error. For the sake of simplicity, the number of variable factors was made five and the number of categories in which each might occur was limited to two. If the variables and the categories are made sufficiently numerous, the curve of normal error can be approximated within any desired degree of exactitude. It is unnecessary to point out the empirical fact that when the sizes, weights, etc., of organisms or their parts are divided into classes and the

[11] *Cf.* B. E. Livingston, *loc. cit.*

[12] E. Baur, "Einführung in die experimentelle Vererbungslehre," 2te Auflage, 1914. L. Jost, "Vorlesungen über Pflanzenphysiologie," 3te Auflage, 1913.

classes are plotted against the number of individuals in each class, the resulting curve approaches the normal curve of error, if a sufficiently large number of individuals are used. Exceptional instances of curves with more than one maximum, or only parts of curves, are easily accounted for and for convenience will be left out of consideration. Since the empirical data bear out the conclusions arrived at by the above procedure, the explanation may be considered valid.

However, the explanation involves the addition of the values of the various factors, which is in reality averaging them, since their value is measured in terms of net gain or loss. Although this process of averaging the various factors involved is borne out by comparing the results with empirical data, it is done, nevertheless, in contradiction to the Law of the Minimum. According to this law $n/32$ should be $+1$ and $31n/32$ should be -1, because *all* the factors are $+1$ in only one permutation, and -1 occurs in all the others and would be a limiting factor. The curve that would result if the Law of Minimum held would start from one at the upper end of the scale of sizes, weights or what not and would rise with great rapidity toward the lower end, where it would reach its maximum. This kind of curve is not the rule.

Every case where Galton's Law holds is a case where the Law of the Minimum does not hold. The resultant size or weight of an organism, which is a measure of its growth, shows that this is not determined by the limiting factor of its environment, but represents some sort of average between all the factors involved. In other words, a process of compensation or integration has taken place, the factors giving the largest values being utilized to some extent at least to alleviate the influence of the limiting factor—a utilization of surplus to cover deficit. Individual processes obey the Law of the Minimum; but the grand total is governed by what may be termed a principle of integration.

The means by which this integration is brought about are not hard to find. At least four important processes are at work in living organisms to this effect, namely—

1. Responses to stimuli,
2. Development,
3. Evolution,
4. Biotic succession.

A few examples will illustrate the way in which integration is effected by each of these. A seedling placed upside down is in the wrong position with respect to the center of the earth, its source of light, and moisture. Position with respect to gravity may be considered to be the limiting factor here; but the germinating rootlet is positively geotropic and bends toward the earth; the young shoot is negatively geotropic and bends away from the earth. In this way these responses to the geotropic stimulus counteract the influence of the limiting factor. Roots behave similarly in response to moisture content of the soil; stems and leaves in response to light.

In plants it is hard to draw a line between simple responses to stimuli and morphogenic responses which involve permanent changes of form and structure. The difference between sun leaves and shade leaves is a familiar example of a morphogenic response. The shape, size and structure of the leaf here counteract the limiting factor light. Again, plants which are shaded by others so that they receive insufficient light usually become etiolated, that is, the stems and leaf-petioles in many cases increase in length until some portion of the plant is brought to a position where it receives adequate illumination. Here again the limiting factor is light, and the result of etiolation is to overcome its effect.

Evolution is likewise an integrating process. Its results are not accomplished

in the individual, but in the race, and are called adaptations. Adaptations are means of avoiding the effects of limiting factors.

Another means of integration is seen in biotic succession. Here the integration extends over a considerable period of time and its benefits do not accrue to the individual or the race, but to succeeding generations and different species. The integrative effect in succession may be largely produced by the death and decay of an association resulting in the accumulation of humus. Thus both xerophytic and hydrophytic plants prepare the way for a mesophytic flora. The limiting factor here is water, which is too scarce in the one case and too abundant in the other. By the accumulation of humus, the properties of the soil are so altered that a more favorable water supply is offered to later generations, and in this way the effect of the limiting factor is counteracted.

All these processes which bring about integration between the relations of living organisms to the factors of the environment that determine their growth and activity are evidently based on a single fundamental principle, to which Professor L. J. Henderson has applied the appropriate misnomer teleology.[13] Wherever integration is found in the factors influencing the individual, the race or the association, it is possible to define a closed system. Such a system includes all the factors which can be integrated, that is, all the possible limiting factors for any given process. These systems may focus about a single cell, an organ, an organism or a group of organisms. They are inclusive. The life of a plant, for example, is determined by a complex of factors between which integration is found to occur. At the same time the functional activity of the root system is determined by another complex of integrated factors, and the functional activity of the leaves by still a different set. Since the life of the root system is dependent on the products of the activity of the leaves, these represent members of the complex which conditions the growth and function of the root system. Such internal factors as enter into the complex of factors centering about the life of a portion of an organism are likewise subject to integration. In this way the condition of the root system affects the leaves and the condition of the leaves affects the root system. Correlations are therefore manifestations of the principle of integration.

The organic world can be analyzed into systems of various orders, those of a higher order being inclusive of, or divisible into, systems of a lower order. These systems are invariably overcoming the effects of limiting factors. The limiting factor is the stimulus to which the system reacts. The reaction places the organism in a more efficient relation with its environment, but no matter how many reactions are carried out, there is always some limiting factor left, and so the organism is kept constantly busy. The end result is to approximate more or less closely some kind of average of all the resources at its disposal.

I think it might be possible to go even further and get a quantitative measure of the degree to which the process of integration has been carried, by considering the number of factors integrated and how close an approximation to the normal curve of error had been obtained. Such a quantitative measure would likewise be an index of the stage of evolution that an organism had reached.[14] At the very least, the Law of the Minimum or the principle of limiting factors offers a sound basis from which such intangible processes as behavior, correla-

[13] The order of nature, 1917.

[14] Our criterion of "degeneracy" in a living organism is based essentially on a decrease in the number or range of factors between which integration is possible.

tions, evolution and ecological succession[15] can be viewed with a clear perspective, if it is not the only scientifically accurate point of view from which to attack such problems.

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THE PECK TESTIMONIAL EXHIBIT OF MUSHROOM MODELS

It is peculiarly fitting at this time to describe rather briefly the exhibit of mushroom models, recently installed in the State Museum at Albany, N. Y., as a memorial to the life and service of the late Charles Horton Peck, state botanist of New York from 1867 to 1915, a period of forty-eight years, all except the last two years having been spent in active service.

The final installation of these remarkable mushroom models was completed only a few days prior to his death, which occurred on July 10, 1917. The models, fifty-seven in number and representing fifty-five species of edible and poisonous mushrooms, are the work of Mr. Henri Marchand, an artist and sculptor of rare ability. The models are made of wax from casts in the field and reproduce with perfect fidelity to nature, the form, coloring and habitat of each species.

Space need not be taken to enumerate the entire list of species represented by the models, but the variety of form and color may be suggested by the following species which are represented in the collection.

Poisonous:

Amanita phalloides
Amanita muscaria
Clitocybe illudens
Russula emetica
Inocybe asterospora

Edible or Harmless:

Amanita caesarea
Tricholoma sejunctum
Tricholoma personatum
Russula cyanoxantha
Lepiota procera
Lepiota naucina
Agaricus campester
Agaricus arvensis
Coprinus comatus
Morchella deliciosa
Gyromitra esculenta
Russula virescens
Strobilomyces strobilaceus
Pleurotus ostreatus
Fistulina hepatica
Armillaria mellea
Boletus cyanescens
Polyporus sulphureus

The services of Dr. Peck in the field of mycology are surpassed by no other American student of fungi. His work, although not confined to the fleshy fungi, is best known from the hundreds of species which he has described in the fleshy and woody groups of fungi (Agaricaceæ, Boletaceæ, Polyporaceæ, Hydnaceæ and Clavariaceæ).

Without the advantages of European travel and study and frequently working without access to the older European literature upon fungi, his work stands out with conspicuous individuality. That he has apparently described in some cases, species already described by the older mycologists of Europe is no reflection upon his remarkable ability in the discernment of specific and generic characters of our native species.

His work will stand for all time as the foundation upon which later students of the fungi may build with safety a more elaborate morphological and systematic revision of the fleshy and woody groups of fungi.

Those friends, admirers and fellow botanists, who have contributed toward bringing into existence this testimonial exhibit of mushroom models may well feel that there is no more suitable memorial possible. There are few pages of modern literature dealing with the fleshy and woody fungi that do not reflect in some degree the individuality of Dr. Peck's work, and looking at these models in the State Museum, with their exquisite variety of form and color, one may imagine with what pleasure and appreciation they would be viewed by him whom they memorialize.

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[15] For an application of the principles enunciated in this paper to plant ecology see G. E. Nichols, *Plant World*, Sept., 1917.

SCIENTIFIC EVENTS

FARM COLONIES FOR TUBERCULOUS SOLDIERS

IT is stated in the *British Medical Journal* that during the past year the National Association for the Prevention of Consumption has urged the formation of farm or garden colonies where discharged tuberculous soldiers, while regaining their health, may be trained in open-air occupations At the annual meeting of the association on July 16, Professor Sims Woodhead sketched his own idea of a model farm colony. It should consist of a large enough tract of land to allow variety in the forms of cultivation introduced. The aim was not only to provide the patient with suitable and congenial work, but also to give him an occupation which should serve him as a means of livelihood, and a part of the farm colony, therefore, should be laid out on a generous allotment system. The colony should serve as an educational center and show how much could be done to improve the conditions of farm workers and the hygiene of farm buildings. To that end every farm colony should be a microcosm in which the maintenance of health and the prevention of infection should be absolutely secured. He thought also that accommodation should be provided for advanced cases. As far as possible, the patients should do the whole work of the colony themselves, and even the overseers should be tuberculous patients who were coming to the end of their term. The patient should help to contribute to the cost by his own labor. The state must provide the land, and it might also contribute towards preparation of the land and erection of the general buildings. But the special buildings, particularly the hospital buildings, should be jointly provided by local taxation, Treasury loan, and voluntary subscription. As the patient got stronger a certain portion of his earnings should be set aside as a bonus for him when he made a new start in life. In the subsequent discussion Sir R. W. Philip suggested that there was some risk of opening the door of the farm colony too wide. If the colony was to be a dumping ground for all grades of tuberculosis, its purpose would be defeated. There must be a clear separation between early and presumably curable cases and dying cases; for the latter, of course, humane provision must be made, but not that of a farm colony. The class of cases to be taken were those which lasted a much longer time than the sanatorium could afford to keep them. Sir William Osler said that the essence of success in the treatment of the consumptive soldier was that he must remain a soldier—that is, he must be under control. Discipline was a very necessary factor in the life of a farm colony. Sir A. Griffith-Boscawen, M.P., parliamentary secretary to the Ministry of Pensions, said that his department had been faced with the difficulty that medical boards had generally assumed that when a man was discharged for tuberculosis the condition was not attributable to military service, and the result was that until lately the man had been turned adrift without pension or other provision. In France in such cases the benefit of the doubt was given to the man. The conditions of the service might at least have brought out the disease earlier than it would otherwise have manifested itself. The policy now was to assume in all cases that the disease was the result of military service unless the contrary was clearly proved.

RESEARCH WORK OF THE RED CROSS IN FRANCE

ANNOUNCEMENT has been made by the Red Cross that its War Council has appropriated $100,000 for medical research work in France. This action follows a report from Major Murphy, Red Cross Commissioner to Europe, who cabled the following from Paris to the National Headquarters at Washington:

> An extraordinary opportunity presents itself here for medical research work. We have, serving with various American units, some of the ablest doctors and surgeons in the United States. Many of these men are already conducting courses of investigation which, if carried to successful conclusions, will result in the discovery of treatments and methods of operation which will be of great use not only in this war, but, possibly, for years afterwards. To carry on their work they need certain special laboratory equipment, suitable

buildings, and animals for experimental purposes. At present, equipment and personnel can not be obtained through ordinary government sources without delay, which makes this source of supply quite impracticable.

Cooperation with Major Murphy in his plans is pledged by Dr. George W. Crile, of Cleveland, who headed the first Red Cross unit to reach France; Dr. Lambert, Dr. J. A. Blake, Colonels Ireland and Bradley, of General Pershing's staff, and various American experts on the ground.

A group of specialists in infant welfare has been sent to France by the American Red Cross. At its head is Dr. William P. Lucas, professor of pediatrics in the University of California.

He reports that there is need for doctors and nurses for work with mothers and children, and the Infant Welfare Unit will be prepared to give such immediate relief as it can. With him in the unit, which was financed by Mrs. William Lowell Putnam, of Boston, are Dr. J. Morris Slemons, of the Yale Medical School; Dr. Julius Parker Sedgwick, physiological chemist, professor at the University of Minnesota; Dr. John C. Baldwin, specialist in diseases of children; Dr. Clain F. Gelston, Dr. Lucas's assistant at the University of California; Dr. N. O. Pearce, another specialist, and the following experts in sociology and child-welfare work: Mrs. J. Morris Slemons, Mrs. William P. Lucas, Miss Elizabeth Ashe and Miss Rosamond Gilder, daughter of the poet. These specialists will survey the situation and study the work already being done by the French, and will practice without receiving compensation from patients. The task before the Red Cross, which will be carried on by this and succeeding units, is not only to cooperate with French specialists, but also to carry on a general educational campaign among French mothers in the interest of better prenatal hygiene and scientific feeding and care of the babies. Special efforts will be made to protect children from tubercular infection, which is particularly threatening France to-day as a result of trench warfare.

WAR DEMONSTRATION HOSPITAL OF THE ROCKEFELLER INSTITUTE

As has been noted in Science the Rockefeller Institute for Medical Research has recently opened a War Demonstration Hospital, on the grounds of the Institute, at Avenue A and 64th Street, New York, the funds for this purpose having been provided by a special appropriation of the foundation.

The purposes of this hospital are to treat patients suffering from infected wounds by methods which have been developed in European army hospitals, especially the methods developed by Dr. Alexis Carrel and Dr. H. D. Dakin, in the Military Hospital at Compiègne, France, and to demonstrate these methods in a practical way to American surgeons. The hospital will make no charge for treatment or care.

As a contribution to assist in solving the problem of cantonment, hospital and other temporary construction, the institute has housed the demonstration hospital in a series of portable buildings such as are used in the most improved base hospitals on the western front. In this way the conditions under which hospital work is carried on in France are imitated; at the same time there is demonstrated a method of knock-down construction which is used to a large extent at the front.

The War Demonstration Hospital is a double-walled construction with a double roof. It is thus well protected against both heat and cold; it is heated by steam, experience having demonstrated the desirability of steam in laundries, kitchens and wards, where more than 300 beds are installed.

The plan of the temporary hospital at the Rockefeller Institute was made by Mr. Charles Butler, a New York architect, who has for a year and a half studied French and British hospital construction in France; he collaborated with the French war department in designing hospitals.

On the basis of this experiment, it is probable that such hospitals could be erected and equipped in almost any part of the country at the rate of $700 a bed for a 500-bed installation.

Dr. Carrel has been granted leave of absence by the French government to come to New York to give personal supervision of the work of the temporary hospital. He is assisted in his work by Dr. Adrian V. S. Lambert, of the College of Physicians and Surgeons.

The war demonstration hospital has been organized with the approval and active cooperation of the war and navy departments. In admitting surgeons to follow the demonstrations and cases that are treated, preference will be given to members of the army and navy medical corps.

THE MATHEMATICAL ASSOCIATION OF AMERICA

The second summer meeting of the association will be held by invitation of Western Reserve University and Case School of Applied Science at Cleveland, Ohio, in conjunction with the summer meeting of the American Mathematical Society, beginning with a joint dinner at 6:30 o'clock Wednesday evening, September 5, and a joint session at nine o'clock Thursday morning, September 6, and continuing Thursday and Friday. The meeting of the American Mathematical Society begins Tuesday morning, September 4. The meetings will be held in the lecture room of the Physics Building of Case School of Applied Science.

The program committee consists of C. S. Slichter, Chairman; L. S. Hulburt, and E. J. Wilczynski. The program is as follows:

THURSDAY, 9:00 A.M.

Joint session of the Mathematical Association of America with the American Mathematical Society. Address by Professor L. P. Eisenhart, of Princeton University—"Darboux's contribution to geometry."

10:30 A.M.

"Undergraduate mathematical clubs"—Professor H. E. Hawkes, Columbia University. Discussion, led by Professor R. C. Archibald, Brown University, and Professor D. A. Rothrock, Indiana University.

2:00 P.M.

Presidential Retiring Address: "The significance of mathematics"—Professor E. R. Hedrick, University of Missouri. "Geometry for juniors and seniors"—Professor E. B. Stouffer, University of Kansas. Discussion, led by Professor Arnold Emch, University of Illinois, and Professor L. W. Dowling, University of Wisconsin.

FRIDAY, 9:30 A.M.

"The treatment of the applications in college courses in mathematics"—Professor L. C. Plant, Michigan Agricultural College. Discussion, led by Professor W. B. Carver, Cornell University, Professor G. H. Ling, University of Saskatchewan.

The committee on arrangements consists of T. M. Focke, Chairman; F. N. Cole, W. D. Cairns, E. V. Huntington, A. D. Pitcher, and D. T. Wilson. Members and visitors are requested to register as early as possible; this will be a distinct aid in helping those in attendance to become acquainted with one another and thus further one of the chief aims of the meetings. Registration will be held in the library of the Physics Building of Case School of Applied Science. It is hoped that, as at the meeting last year in Cambridge, members may wish to bring their wives to share in this sojourn in Cleveland and in the social hours which always accompany the meetings.

Hotel Statler has been selected as the official headquarters for the summer meetings of the American Mathematical Society and the Mathematical Association of America. Luncheon will be served each day, to those attending the meetings, at the Case Club. This building will be at the disposal of members and their friends for the afternoons and evenings during the meetings. The joint dinner of the Association with the American Mathematical Society will be held at the Hotel Statler, Wednesday evening, September 5.

W. D. CAIRNS,
Secretary-Treasurer

OBERLIN, OHIO,
August 18, 1917

JOHN OREN REED AND KARL EUGEN GUTHE

TABLETS to the memory of John Oren Reed and Karl Eugen Guthe were unveiled in the physics building of the University of Michigan at commencement. Following a short address by Professor Harrison McA. Randall, of

the Department of Physics, they were accepted in behalf of the university by Regent J. E. Beal. The tablets were the gifts of former students and colleagues and were inscribed as follows:

THIS TABLET IS ERECTED BY
FRIENDS AND FORMER STUDENTS OF
JOHN OREN REED
1856–1916
PROFESSOR OF PHYSICS AND DEAN OF THE DEPARTMENT OF LITERATURE, SCIENCE AND THE ARTS, IN MEMORY OF HIS TWENTY-FOUR YEARS OF FAITHFUL SERVICE AS A TEACHER AND IN GRATITUDE FOR THE INSPIRATION GIVEN THEM BY HIS STAUNCHNESS OF CHARACTER AND BY HIS UNSWERVING DEVOTION TO TRUTH AND TO PROGRESS.
MDCCCCXVII

TO
KARL EUGEN GUTHE, PH.D.,
BORN MARCH 5, 1866.
DIED SEPTEMBER 10, 1915.
AN EMINENT PHYSICIST, A BELOVED TEACHER, PROFESSOR OF PHYSICS AND DEAN OF THE GRADUATE SCHOOL OF THIS UNIVERSITY
THIS TABLET IS ERECTED BY
HIS STUDENTS AND COLLEAGUES
IN AFFECTIONATE REMEMBRANCE
MDCCCCXVII

SCIENTIFIC NOTES AND NEWS

Adolf von Baeyer, professor of chemistry at Munich, distinguished for his work on synthetic indigo and in other directions, has died at the age of eighty-two years.

The death is also announced of Eduard Buchner, professor of chemistry at Würzburg, who died from wounds while serving as major at the front. Dr. Buchner was distinguished for his work on the chemistry of fermentation, and was the recipient of the Nobel prize for chemistry in 1907.

Dr. G. Müller has been appointed director of the astrophysical observatory at Potsdam, in succession to the late Professor K. Schwarzschild.

The Paris Academy of Sciences has elected the following eight members as a committee on scientific research: MM. A. Laveran, from the section of medicine and surgery; Th. Schloesing, from the section of rural economy; Edm. Perrier, from the section of anatomy and zoology; J. L. Guignard, from the section of botany, and MM. G. Lipmann, E. Picard, A. Gautier, A. Lacroix, from the academy at large.

The Paris Academy of Sciences has awarded prizes in mechanics and mathematics as follows: The Bordin prize of 3,000 frs. has been awarded to M. Gaston Julia, now lieutenant in the army; the Francoeur prize of 1,000 frs. to M. Henri Villat, lecturer at Montpellier for his publications on hydrodynamics; the Montyon prize of 700 frs. to M. René de Sausseure, docent at Geneva, for his work in mechanics; the Poncelet prize of 200 frs. to M. Jules Andrade, professor at Besançon, for his work in applied mechanics, especially chronometry.

Dr. Henry J. Waters, Manhattan, Kans.; Leon S. Merrill, Orono, Me.; Dr. Edwin F. Ladd, Fargo, N. D.; and David R. Coker, Hartsville, S. C., have been appointed state food administrators by the federal government.

Floyd R. Harrison, connected with the Department of Agriculture since 1906 in various capacities, has been appointed an assistant to the Secretary of Agriculture during the present emergency.

Mr. F. F. Longley, a member of the firm of sanitary engineers of Hazen and Whipple, has been made a major and sent to France to assume complete charge of the water supply for the American forces.

Dr. Hugo Diemer, professor of industrial engineering in the Pennsylvania State College, has accepted a commission as major in the Ordnance Section of the Officers' Reserve Corps.

The American Red Cross has appropriated $800,000 to meet sanitary emergencies in the civilian areas surrounding army cantonments. A bureau under the direction of Dr. W. H. Frost, of the Public Health Service, will have charge of the work. The Red Cross will undertake such sanitary management only by request of the local organization in charge.

Dr. Victor G. Heiser, director of the Department of the East of the International

Health Board of the Rockefeller Foundation, is a member of the commission of the Red Cross which is making a survey of conditions in Italy, preliminary to a possible appropriation for relief by the Red Cross. Dr. Heiser has also consented, if the matter is undertaken, to head the work of establishing Red Cross relief stations in seaports having military significance for the United States and its Allies.

PROFESSOR WALTER T. FISHLEIGH, of the University of Michigan, has been commissioned as major, to act as automobile engineer to the U. S. Medical Corps in charge of the engineering, testing, inspection, maintenance and repairs of all American ambulances in the army, both in this country and abroad. Professor Felix W. Pawlowski, also of the University of Michigan, is in the government service as aeronautical engineer in the signal corps with headquarters at the War Department at Washington.

DR. EDGAR T. WHERRY, for the past four years assistant curator of the division of mineralogy and petrology of the U. S. National Museum, has been transferred to the position of crystallographer in the Bureau of Chemistry of the U. S. Department of Agriculture.

DR. L. E. DICKSON, professor of mathematics in the University of California, has accepted an invitation to be a visiting professor at the University of California for the first half of the coming academic year. He will return to the University of Chicago on December 20.

DR. E. O. HOVEY, curator of geology in the American Museum of Natural History, has reached home safely after an absence of over two years with the Crocker relief expedition.

DR. A. W. GILBERT, professor of plant breeding at Cornell University, who has been on leave of absence for graduate work in rural economics at Harvard University, has resigned to accept an appointment with the Boston Chamber of Commerce. Donald K. Tressler, assistant in agricultural chemistry at the university, has also resigned to accept a position with the Bureau of Soils of the U. S. Department of Agriculture.

DR. MARK FRANCIS, of the Agricultural and Mechanical College of Texas, recently secured the vertebræ of some dinosaurs from the vicinity of Riesel near Waco. He has added these to the collection of Texas vertebrate fossils which he has been accumulating for some years and which includes the type specimens of *Equus Francisii*, named by Dr. O. P. Hay, of the National Museum, from material found near Eagle Lake, Texas.

THE surgeon-general's office desires the names, addresses and ages of men in each class of every reputable medical school who have been drawn and accepted for military service under the provisions of the selective draft, these names to be vouched for by the deans of the respective medical colleges.

THE board of health of Akron, Ohio, is seeking a health officer to take charge of the board of health, the salary of the position being $3,500.

THE National Bureau of Standards has not yet obtained all the men needed to fill metallurgical positions with salaries varying from $1,200 to $2,000, depending upon the training and experience of the candidate. Men are desired with experience either in ferrous or nonferrous metallurgy. The duties in such positions will be almost entirely of an investigational nature, in connection with problems of military importance. Qualified men are urged to communicate to the Bureau of Standards at once a statement of training and experience, names of references, and minimum salary which would be accepted, so that they may be advised of appropriate civil service examination for which to file papers. Until further notice such papers are received by the Civil Service Commission at any time and rated promptly.

The Experiment Station Record states that as a result of experiments conducted by the department of chemistry of the South Dakota Agricultural College during the past twenty years, it is expected that sugar-beet factories will soon be established in both the eastern and

the western part of the state. Information from western South Dakota, where sugar beets are being raised on a large scale, shows that the price of land has greatly increased. The loss of so many sugar factories in Belgium and France is reported as stimulating efforts to produce more sugar in this country.

UNIVERSITY AND EDUCATIONAL NEWS

Dr. Henry Freeman Walker has bequeathed $100,000 to Middlebury College, to provide full salary for a professor on Sabbatical leave, any balance is to be used as an emergency fund for members of the faculty.

The *Experiment Station Record* states that provision has been made by the Texas legislature for establishing a third junior agricultural college, to be known as the Northeast Texas Agricultural College. An appropriation of $250,000 has been made for its establishment and maintenance. The board of directors of the State Agricultural and Mechanical College is given control over the institution. State appropriations have also been made for the station and substations aggregating $225,095 for the year beginning September 1, and $181,270 for the following year.

A chair of aviation has been founded in the London University by M. Basel Zaharoff, who before the war had established similar professorships in the universities of Paris and of Petrograd.

Ross Aiken Gortner, Ph.D. (Columbia), associate professor of agricultural biochemistry in the University of Minnesota, has been appointed professor and head of the division of agricultural biochemistry in the university and chief of the division of agricultural biochemistry in the Minnesota Agricultural Experiment Station, succeeding R. W. Thatcher who becomes dean and director of the department of agriculture in the same institution. R. Adams Dutcher, assistant professor of agricultural chemistry in the Oregon Agricultural College, and Clarence A. Morrow, professor and head of the department of chemistry in Nebraska Wesleyan University, have been appointed assistant professors of agricultural biochemistry in the University of Minnesota. Clyde H. Bailey, cereal technologist and assistant professor of agricultural chemistry in the University of Minnesota, who for the past year has been on leave of absence and has been employed as chemist for the Minnesota State Board of Grain Appeals, Minneapolis, has resumed his duties in the university and has been promoted to an associate professorship in the division of agricultural biochemistry.

C. W. Howard, associate professor of entomology and parasitology of the University of Minnesota, has accepted the position of professor of biology in Canton Christian College, Canton, China. Professor Howard will sail from San Francisco the middle of October, visiting Hawaiian Islands, Manila and Japan *en route*. Canton Christian College is the only institution of collegiate rank in South China. The rapid growth of the agricultural and medical departments has made necessary the organization of a department of biology.

Dr. L. B. Arey has been promoted from instructor to associate professor of anatomy in the Northwestern University Medical School.

Dr. Raymond Freas has been appointed adjunct professor of chemistry in the University of Virginia.

Dr. J. Arce has been appointed to a newly established chair of tropical pathology in the University of Lima, Peru.

DISCUSSION AND CORRESPONDENCE

THE INTERPRETATION OF THE RESULTS OF FIELD EXPERIMENTS WITH DIFFERENT PHOSPHATES

The interpretation of results of field experiments with different phosphates is of present interest, especially as the conclusions reached by several investigators are being challenged by Dr. C. G. Hopkins, of the Illinois Agricultural Experiment Station.[1] As is well known, Dr. Hopkins has for several years been the ardent champion of raw rock phosphate as a fertilizer. He has been largely dependent, however, on data secured by others. In fact, not until very recently had he published re-

[1] Hopkins, C. G., "Phosphates and Honesty," Ill. Agri. Exp. Sta., Circular 186.

sults of his own experiments in which different phosphates were compared.

Statements[2] recently made by him in regard to the conclusions drawn in Bulletin 90 of the Tennessee Agricultural Experiment Station even go so far as to impugn the ability of an author who would draw the conclusion that bone meal proved to be, in those experiments, superior to rock phosphate. In view of the detailed data contained in Bulletin 90, the writer is surprised that there should be any serious differences of opinion in the matter. Careful consideration has convinced him that Dr. Hopkins has laid unwarranted stress on a single table (XIII.), which gives some averages from the three longest-continued experiments, and that he has failed to give due weight to the results of the individual series. This raises a question as to the value of such a table, especially to the casual reader, for it is evident that if a short number of series be averaged a preponderance of a single series may distort or mask the true findings. Such a table, therefore, is open to criticism, and evidently should be used with discretion, but is justified as one way of presenting a summary.

Table XIII. of Bulletin 90 gives as stated, a summary from three series of experiments each conducted on a different type of soil. Series 1, as is pointed out on pages 69 and 70 and again on page 87 of the bulletin, was conducted on a soil which proved to be naturally too well supplied with phosphoric acid to be at all well adapted to the comparison desired, so much so that rock phosphate in the last four years of the five-year period proved unprofitable in three of the eight experimental conditions. Excessive growth with lodging reduced the yields of wheat on one half the bone-meal plots, and even acid phosphate was used with only a narrow margin of profit. The soils of the other two series proved, however, to be poor in phosphoric acid and hence well suited to a comparison of phosphates.

In series 2 the evidence is unsatisfactory because of the lack of agreement between the results of the two rock phosphate plots, one of which shows a slight loss and the other a good profit from the use of rock phosphate. If the latter be compared with the near-by bone-meal plots the rock phosphate shows more profit. In series 3, which was conducted on a soil especially poor in phosphoric acid, the evidence is decidedly in favor of bone meal as compared with rock phosphate. Under every one of the four experimental conditions of this series bone meal made a large increase in yield—equal, in fact, to the best obtained from acid phosphate and averaged 5.6 bu. of wheat per acre more than that obtained from rock phosphate. Even when calculated on the dollar-investment basis used by Dr. Hopkins, the average acre profit from $1.00 invested in bone meal was $3.05 as compared with $2.79 for rock phosphate. In this connection it should be mentioned that a comparison between bone meal and rock phosphate where the cowpeas were removed for hay was omitted in Table XIII. because only in series 3 was such a comparison made, the results being especially favorable to bone meal.

Series 4, which was not included in Table XIII., is also worthy of consideration. This series was conducted on a greatly impoverished type of soil, well known to be naturally poor in phosphoric acid. As measured by the yields of wheat, acid phosphate proved highly profitable, but both bone meal and rock phosphate were used at a loss. However, the writer's records and observations of these experiments, during the two years of their continuance, convinced him that bone meal could be used profitably in the reclamation of land of this character. On the other hand, rock phosphate appeared next to worthless. By way of confirmation, bone meal plots 9 and 11 produced in the second year an average of 1.41 ton of cowpea hay to an acre. The near-by rock phosphate plots 7 and 8 produced only 0.80 ton. The value of the difference between the two yields of hay would pay for the bone meal used and leave a good profit. The hay data were not given in Bulletin 90, but serve as a good illustration of the advantage in the interpretation of results that rests with the person conducting the experiments.

[2] SCIENCE, November 3, 1916, p. 652.

In drawing his conclusions with regard to the showing made by the different phosphates, the writer was governed chiefly by a consideration of the soil conditions and results of the individual series and, as he thinks, very naturally placed acid phosphate first, bone meal second, and rock phosphate third in profitableness.

With all the individual series in view, let us see the kind of formula Dr. Hopkins must use in order to arrive at his conclusion with regard to the relative standing made by bone meal and rock phosphate. The formula and his conclusions may be stated as follows:

Disregard series 4, omit one half the bone-meal data of series 3, include series 1 (conducted on a soil not poor in phosphate), and with the acid of series 2 obtain averages which show that, as used, the bone meal returned more profit than the rock phosphate. Now, make the unwarranted assumption that the profit from bone meal would decrease in direct proportion to the quantity used, and obtain the result that a dollar invested in rock phosphate made a profit of 39 cents more than a dollar invested in bone meal, or, the rock phosphate was superior to the bone meal. Q. E. D.

In Science, March 2, 1917, page 214, Dr. Hopkins says: "The calculated profits mentioned in Professor Mooers's Science article[3] are evidently based upon different valuations than those reported in the bulletin." The writer finds that the calculated profits for both acid phosphate and rock phosphate, as given in the Science article referred to, should be divided by 2. This, of course, does not affect the relative standing of the two materials. One dollar invested in acid phosphate shows an average profit of $2.14 per acre where the cowpea crops were turned under, and of $2.71 where removed, but one dollar invested in rock phosphate gave an average return of only $1.29 under either condition. The writer has assumed that Dr. Hopkins could give a simple explanation for his conflicting estimates, as given in Science, November 3, 1916, p. 652, and in Science, March 2, 1917, p. 214. In the former article he says, "For each dollar invested rock phosphate paid back $2.29," but in the latter article he says, with regard to the same data, "Easy computations show profits per $1.00 invested of . . . $1.29 from phosphate rock."

From correspondence with dealers in rock phosphate, the writer is informed that until about six years ago the usual guarantee of fineness for the rock phosphate sold to farmers for fertilizer purposes was that 90 per cent. would pass through a 60-mesh sieve, but that the present guarantee is for 90 per cent. to pass through a 100-mesh sieve. Dr. Hopkins seems to have this in mind when he says, "Raw rock phosphate is now procurable in very much better mechanical condition than when these experiments were conducted."[4] That he was in error with regard to the rock phosphate used in the experiments referred to may be seen by reference to page 59 of Bulletin 90, where the following statement is made: "90 per cent. was found to pass through a 100-mesh sieve."

In conclusion, the writer will add, that on page 60 of Bulletin 90, the content of total phosphoric acid in the rock phosphate was stated to be 33.9 per cent. The usual guarantee and expectancy for this material, as sold to farmers for fertilizer purposes, is a little under 30 per cent. With perfect fairness the calculations for phosphate rock used in the experiments might have been placed on the latter basis, and an increase of 13 per cent. can be properly allowed—as was referred to on page 59 of the bulletin—to the estimated cost of the applications made. This change would appreciably increase the unfavorable showing made by the phosphate rock.

C. A. Mooers
Agricultural Experiment Station,
University of Tennessee

[3] Science, January 5, 1917, pp. 18 and 19.

[4] Science, March 2, 1917, p. 214.

A METHOD FOR OBTAINING AMŒBA

In common with many teachers I have found it necessary, at the opening of college in the fall, to provide large numbers of the indispensable amæba. I venture to set down a method which I have found successful during

several years. Publication of other methods for obtaining a large and more or less continuous supply of these animals has not been infrequent and many are familiar with use of *Elodea* (*Philotria,* Michx.-Britton), *Ceratophyllum* and other aquatic plants.

The ditch-moss is not readily found in many localities. My personal experience with several aquatic plants yielded indifferent results and failed to give sufficient numbers until, by chance one season, I tried the marsh plant, *Elodes campanulata* (*Triadenum virginicum* (L.) Raf., see Britton and Brown) and was rewarded with large numbers of amœbæ. Although absence from town in some seasons occasioned a too long interval between the times of collection and the use of the material, or made it impossible to provide the proper sequence of cultures, I have seldom been disappointed in finding the animals, though they may not have come just when wanted.

The usual custom was followed in making up the cultures. Crystallizing dishes or battery jars—the shallower dishes gave the better results—were crowded not too densely with the stems of the plants. The stems were usually cut two or three times. Tap water and water from the pond or marsh where the plants were collected were used, separately, but no difference in results was noted. The dishes were covered with plates of window glass, placed in a room of moderate temperature and there allowed to remain in diffuse light for a period of three weeks or more. When pains were taken to collect the plants at intervals and provide a sequence of cultures the results were most gratifying.

I have used the plant from four different localities, collecting from the water and from banks where the plants could only have been submerged at high water and mixing, with success in all cases. Since the locality seems not to be a controlling factor, and since the cultures of tap as well as pond water yield the animals, I assume that the *Elodes* is favorable for the original lodgment of amœbæ and their later multiplication.

C. E. GORDON
AMHERST, MASS.

CROSSING-OVER IN THE SEX CHROMOSOME OF THE MALE FOWL

SEVERAL years ago an experiment was begun with the object of studying the inheritance of several sex-linked characters associated in the same individual, but the experiment had to be laid aside until last year. The second generation chicks are now at hand and prove beyond doubt that crossing-over takes place between the sex chromosomes of the male fowl.

In this preliminary report attention will be confined to the factors themselves, without regard to the somatic appearances of the individuals. Three dominant sex-linked characters, viz., B, I, and S were employed. B and I were introduced on one side; S, on the other. Hence the F_1 males were all BI, S,; B and I being in paternal (or maternal) sex chromosome, S in the maternal (or paternal). These males have been tested by mating them back to females of the composition b Is, b is.

If there were no crossing-over, offspring of this back cross showing the combination of somatic characters found in the F_1 male, would not occur. Actually, however, they do occur, thus demonstrating that crossing-over has occurred, a chromosome having the composition B I/S, having been formed. Other cross-over classes have appeared, but the one cited is the one at the present age of the chicks, most easily recognized.

No crossing in the female is to be expected on theoretical grounds. None was observed in the original cross. Partly because of practical reasons and partly because no new combinations were available in F_1, it seemed wise to defer a test of this point until next season, when the new combination B I S should be available in the mature female.

H. D. GOODALE
MASSACHUSETTS AGRICULTURAL EXPERIMENT STATION

THE EQUAL PARALLAX CURVE FOR FRONTAL AND LATERAL VISION

IN the article by Mr. C. C. Trowbridge on "The importance of lateral vision in its relation to orientation"[1] is given an equal parallax curve showing the distances that a man

[1] SCIENCE, N. S., Vol. XLIV., No. 1135, pp. 470–474, September 29, 1916.

and a bird must move forward to give the same apparent displacement of objects against the horizon. It is the purpose of the following note to derive an analytic expression for this curve.

Consider first the case of lateral vision. Let A be the starting point of the bird, and let the two objects, A_1 and A_2 in the original axis of vision be at the distances a_1 and a_2, respectively, from A. Let y be the distance that the bird moves forward, and α the angle that is subtended at its eye by the distance A_1A_2. (See Fig. 1.) Then

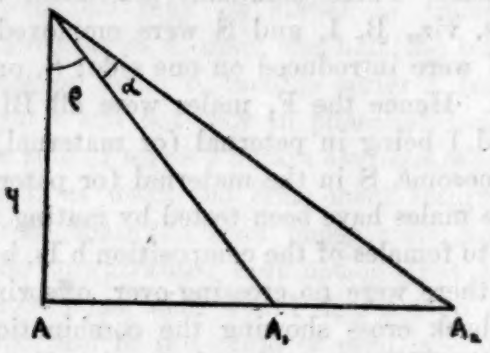

Fig. 1.

$$(1) \qquad \tan(\alpha+\beta)=\frac{a_2}{y}, \quad \tan\beta=\frac{a_1}{y},$$

where β is defined in the figure. Using the trigonometric formula for the tangent of the sum of two angles, and replacing $\tan\beta$ by its value from the second equation of (1), we get

$$(2) \qquad \frac{y\tan\alpha+a_1}{y-a_1\tan\alpha}=\frac{a_2}{y}.$$

Solving this for y gives

$$(3) \qquad 2y\tan\alpha=a_2-a_1\pm\sqrt{(a_2-a_1)^2-4a_1a_2\tan^2\alpha}.$$

In taking up the case of frontal vision, it is necessary, as Mr. Trowbridge states, to have a deflection between the line connecting the observed objects and the direction of the man's motion. Designating the angle of deflection by δ, and the distance that the man moves from A by x (see Fig. 2), we have by the law of sines

$$(4) \qquad \frac{x}{a_1}=\frac{\sin(\gamma+\delta)}{\sin\gamma}=\cos\delta+\cot\gamma\sin\delta,$$

where again $AA_1=a_1$, $AA_2=a_2$, and α is the angle subtended at the eye of the observer by AA_1. The angle γ is defined in the figure. Also

$$(5) \qquad \frac{x}{a_2}=\frac{\sin(\alpha+\gamma+\delta)}{\sin(\alpha+\gamma)}.$$

By using the value of $\cot\gamma$ obtained from (4), we can easily eliminate γ and reduce (5) to

$$(6) \qquad \frac{x}{a_2}=\frac{x\sin(\alpha+\delta)-a_1\sin\alpha}{x\sin\alpha-a_1\sin(\alpha-\delta)}.$$

Solving for x gives

$$(7) \qquad 2x\tan\alpha=a\pm\sqrt{a^2-4a_1a_2\tan^2\alpha},$$

where

$$a=(a_2+a_1)\cos\delta\tan\alpha+(a_2-a_1)\sin\delta.$$

Equations (3) and (7) then are parametric equations of the equal parallax curve.

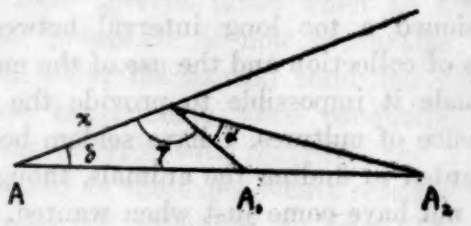

Fig. 2.

In plotting the curve of the practical problem we assign the values $x=0$, $y=0$ for $\alpha=0$. To a value of α slightly greater than zero will correspond two values of x from (7) and two values of y from (3). It is easily seen that for the practical problem the smaller of these must be chosen in each case; that is, we must use the negative sign before the radicals in (3) and (7). For Mr. Trowbridge's curve the special values $a_1=1{,}000$, $a_2=2{,}000$ must be assigned, and in all instances δ must of course be known.

Paul R. Rider
Washington University,
St. Louis, Mo.

A PREDECESSOR OF PRIESTLEY

To the Editor of Science: The notice of the Priestley Memorial in the issue of Science for August 17, 1917, reminds me of the best chemical joke I have ever heard. I can hardly forgive the "new chemistry" for having spoiled it. At our Brown University club dinners in Philadelphia we never have any wine. Many years ago when water was "HO" the late Rev. Dr. H. Lincoln Wayland, the best wit I ever have known, after a very happy eulogy of water, ended his after-dinner speech

in the following manner: "Our chemists tell us, forsooth, that the composition of water was unknown until Priestley discovered oxygen in 1774. Never was there a greater mistake, for did not the prophet cry out, ages ago, 'HO! Everyone that thirsteth.'" W. W. KEEN

PHILADELPHIA, PA.,
August 20

SCIENTIFIC BOOKS

The Physical Basis of Society. By CARL KELSEY, Professor of Sociology in the University of Pennsylvania. New York. D. Appleton & Co. 1916. Pp. xvi + 406.

As its name indicates, this book deals chiefly with the physical basis of human society. The following subjects are considered in sequence: the earth and man, mutual aid and the struggle for existence, the control of nature, the evolution of man, heredity, heredity and society, race differences, sex differences, the influences of society upon population, social institutions, and the nature of progress.

In the chapter on the earth and man, the author introduces too much detail for an elementary sociological work, especially on pages 1 to 28. Moreover, the real social significance of much of the material is not clearly shown. It would have been much better if the author had developed such a topic as the size and customs of the social group as influenced by the prevailing method of food getting, which is conditioned by physical environment.[1] Pages 28 and following give a fairly satisfactory summary of geographic influences.

In the chapter on mutual aid and the struggle for existence, the author again loses himself in a mass of ill-digested detail about the chemical and bacteriological aspects of plant life, and devotes to this subject space out of all proportion to its sociological significance.

The chapter on the control of nature is done more successfully, but the chapter on the evolution of man is very unsatisfactory. In this latter chapter the author launches into a discussion of the old controversy about the evolution of man. He has reduced statements and quotations from authorities to such small compass that their real meaning and spirit are largely lost. At present, when students are generally open-minded in regard to the doctrine of evolution, it is a waste of time to revive this theological controversy in a book that is non-historical. The real subject-matter of this chapter, if the title is any indication of its aim, is treated in a few scant pages at the end.

The chapter on heredity is superior to any of the preceding and is a good treatment of the subject. The clarity of presentation might have been improved by better selection of diagrams. The chart on page 236 illustrating the inheritance of polydactylism, although taken from such a reliable source as Guyer, is not well selected to illustrate the inheritance of a dominant trait. An analysis of this chart reveals the fact that the transmission of polydactylism as a Mendelian trait in the family shown, is explicable only on the assumption that it is a recessive—and this contradicts the caption. But explanation of the chart in terms of the sex-limited hypothesis does, however, permit its interpretation in terms of dominance. Yet the author has not introduced this qualification, hence the example is not satisfactory. The remaining chapters are superior to the earlier ones.

In general, the book gives all appearances of having been too hastily written, and thus furnishes grounds for the criticism that the work of sociologists is superficial. This is all the more deplorable because the general plan and logic of arrangement of the book are excellent. F. STUART CHAPIN

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Recreations in Mathematics. By H. E. LICKS. New York, D. Van Nostrand Co. 1917. Pp. v. + 155, $1.25.

This is an amusing little book with various problems of more or less interest, particularly to the teacher of elementary mathematics. Unfortunately the historical notes are largely

[1] See Ellen Semple's "Influence of Geographic Environment," pp. 54 to 65.

incorrect. In addition to mathematical problems and random notes on elementary mathematics through the calculus there are similar notes on astronomy and the calendar, and on mechanics and physics.

Louis C. Karpinski

SPECIAL ARTICLES

THE EFFECTS OF THYROID REMOVAL UPON THE DEVELOPMENT OF THE GONADS IN THE LARVÆ OF RANA PIPIENS

In a paper published in Science, November 24, 1916, a general account was given of my experiments performed in the spring of 1916 upon the removal of the anlagen of the anterior lobe of the hypophysis and of the thyroid gland in early tadpoles of *Rana pipiens*. It was shown that in each case this operation prevented metamorphosis. A full account of the results of the removal of the anterior lobe of the hypophysis has been published.[1]

Now the effect of thyroid removal upon the development of the gonads has been largely worked out. A full account of this latter phase of the work will be published in due time, together with papers by students of mine who have worked along correlated lines. It seems desirable in the meantime to give a brief account of the most interesting theoretical results of my investigations.

It was shown in my earlier paper that in the absence of the thyroid gland the tadpoles failed to undergo metamorphosis. Development went on normally up to the time when the hind limbs reached a length of 4–5 mm. At this stage the limbs entirely ceased to develop while the body as a whole failed to undergo further differentiation. While the tadpoles increased very greatly in size they at no time showed any further evidences of metamorphosis. This was true in spite of the fact that they eventually attained a length of body—exclusive of tail—varying from 30 to 43 mm. These figures are far in excess of any length normally attained by tadpoles of this species. From time to time specimens were killed and studied. At the date of writing, March 20, two of these tadpoles still remain alive and are in the same stage of bodily differentiation that they had reached the last of June.

This not only involves leg length, the failure of the tail to decrease in length and the failure of the mouth to change in form, but it involves the retention by the intestine of the original relative length characteristic of tadpoles. The lateral line organs became more highly developed than ever. In short a strictly larval form is maintained for months.

Now it is true that failure to metamorphose may likewise be attained by insufficient feeding if brought about at a sufficiently early stage of development. One larval tadpole with hind legs 5.5 mm. in length was kept in its larval condition by feeding very meagerly to November 15. At that time an effort was made to cause it to increase in size and to attain metamorphosis. Although it ate food it remained quite small, not showing any marked increase in size, nor did it show any strong tendency toward metamorphosis. When killed Febaruary 22 the testes were found to be quite small, they showed spermatogonia but no tendencies toward spermatogenesis. This was in strong contrast to the condition in a thyroidless tadpole with a body length of 43 mm. killed February 7. In this tadpole the testes were well developed, spermatogenesis was most active and thousands of completely formed spermatozoa were found in the testes, although the tadpole had remained in a strictly larval form with hind limbs only 5.5 mm. long and with a stomach and intestine length of 426 mm.—over 12 times the length of the corresponding organs in normal frogs at the time of metamorphosis.

The above cases are compared in order to show that although starvation may serve as one means of retarding metamorphosis, it also retards the development of the gonads and of the contained germ cells. This has been thoroughly established in an unpublished paper by Mr. Wilbur Swingle, one of my graduate students who carried out a series of experiments upon this same species. This case is cited to obviate the objection that the conditions here set forth might have been produced by starvation and not in thyroidless tadpoles

[1] *Biological Bulletin*, March, 1917.

properly fed. The continued development of their gonads and germ cells, and the normal metamorphosis of the similarly fed controls all show conclusively that we are here dealing with conditions resulting from the removal of the thyroid glands.

It must be kept in mind that the thyroid anlagen were removed at their very inception. It is fair to say that in these tadpoles there has never at any time been any thyroid secretion. A careful study of serial sections has demonstrated with certainty the total absence of these glands in the crucial cases used as a basis for this work.

The germ glands of the thyroidless tadpoles develop quite normally throughout, both as to structure and rate of development. When the operated tadpoles begin to lag behind the controls in general bodily differentiation, the gonads have already undergone sexual differentiation but have not yet shown any tendencies toward spermatogenesis. The remarkable feature of these experiments is seen in the fact that although differentiation of the soma halts completely at this early stage, the gonads continue to develop normally, keeping pace at every stage with the development of the gonads in control specimens. This applies both to the development of the gonads as a whole and to the development of sperm and ova.

At the time of metamorphosis the testes of both controls and thyroidless specimens showed similar dimensions. In no cases were there evidences of spermatogenesis. A thyroidless tadpole killed September 14 showed very active stages of spermatogenesis terminating in the production of many spermatids; but as yet no spermatozoa. Ripe spermatozoa were, however, found in a thyroidless tadpole killed December 15. In this case they were few in number, but in a thyroidless tadpole killed February 7, to which reference was made above, they were very numerous. This latter specimen had testes nearly twice as large as those of young frogs at the time of metamorphosis and of course very far beyond the condition found in tadpoles of a similar stage of body differentiation.

No less striking were the conditions in female specimens. At the time of metamorphosis, the central cavity of the ovary had formed, but the organ had not yet become folded as was later to be the case. All but a few scattered germ cells had become converted into large oocytes. An average of 12 of the largest measured showed dimensions of .2025 mm. $\times$ .2502 mm. As time passed, the thyroidless tadpoles showed continued growth of the ovaries. On February 14 they reached a size twice as great as at the time of metamorphosis. During all this time the oocytes of the thyroidless tadpoles steadily increased in size, as seen in specimens killed from time to time. In a thyroidless tadpole killed February 14 the average dimensions of the oocytes were .4027 mm. $\times$ .5207 mm. It is quite interesting to compare with this the conditions found in a normal young frog that metamorphosed last summer, living in the open and reaching a length of 48 mm. When it was killed March 13 the larger ova were seen to have reached an average size a trifle below that of the case just given, namely, .4123 mm. $\times$ .4540 mm., although the ovaries as a whole were somewhat larger, 8.05 mm. $\times$ 99.2 mm. as compared with 6.6 mm. $\times$ 7.2 mm. in the thyroidless tadpole killed March 15. This is probably due to the difference in bodily nutrition and is about proportional to the length of body of the two specimens compared.

From all this evidence I feel that we are justified in stating that the absence of the thyroid gland does not affect the development of the gonads or germ cells up to the time of sexual maturity in the male nor does it hinder the development of the ovary and ova, at least up to the period when the ova are visible with the naked eye. It is, of course, possible that the astonishing modifications of the soma may later secondarily affect the nutrition of the developing ova, but this is beyond the point.

These results are in line with some unpublished work by Mr. Wilbur W. Swingle, who at my suggestion studied the effects of thyroid feeding upon the germ glands and germ cells of *Rana pipiens* tadpoles. He shows that while this brought about the well-known

result of hastening metamorphosis with all of the attendant modifications, as had been known from the work of Gudernatsch, it did not in any wise modify the rate of development of the germ glands and germ cells.

The most striking result of all is the evidence brought forth to show that germ cells and soma are different in their nature, that the germ cells are unaffected by the thyroid, while the soma is so profoundly influenced by it. It is possible that further work may show that there are other structures that continue their development unhindered in the absence of the thyroid gland, but the work thus far has failed to demonstrate them.

This investigation throws light upon the problem of neoteny. We can with perfect justice say that we are here dealing with a case of artificially produced neoteny in a form which does not show it in nature. Here we can point to a very specific cause for this phenomenon, about which there has been so much conflicting speculation.

Bennet M. Allen
University of Kansas

THE STANSIPHON

Amongst the many interesting and useful pieces of apparatus shown in the scientific exhibit during the Christmas meetings of the American Association for the Advancement of Science was a self-starting siphon, the trade name for which is the Stansiphon.

For the information of those members of the society who did not see the model shown at that time and in the general interest of science, I am giving a brief description of its construction and operation followed by a statement of some of its more practical applications as well as inherent limitations as at present constructed.

The self-starting device is shown in Fig. 1 and consists of a bulb (4) sealed into the lower end of the tube (2) and an inner tube (5) sealed into the base of the bulb and reaching into the opening of the bulb at the top. Here the end is somewhat constricted and its size and position with respect to the top of the bulb is so adjusted that an "air trap" is produced at (6). A small opening (7) is made at the lower part of the bulb.

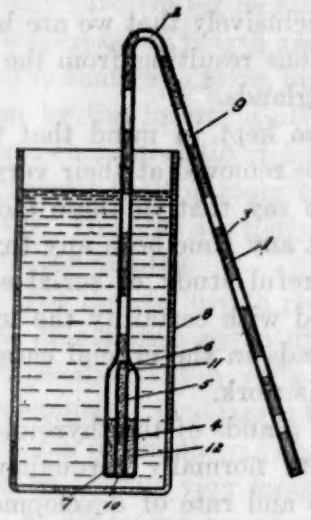

Fig. 1.

If the bulb be inserted to a considerable depth into the liquid to be siphoned, the liquid flows into the bulb through (7) and displaces the air which with the water passing through the inner tube (5) rises in a broken column in tube (2) and flows out through the delivery tube.

The height to which the given liquid may be raised will depend on the size of the bulb, the depth to which it is immersed, the construction of the "air trap," the material of which the siphon is made, the rate at which the bulb is inserted, etc. To operate successfully on ordinary liquids the Stansiphon should be immersed to a depth at least two or three times the length of the bulb.

Preliminary experiments were made by the inventor on water and the present design has greatly increased the efficiency of the siphon, both as to height lifted, and the rate of flow. A design of larger size has been made which successfully siphons acids from carboys, but owing to the heavy density of these acids it works relatively slowly as compared with water. Light oils such as kerosene and gasoline are readily siphoned by this method, but as yet a suitable design depending on this principle has not been found for the heavier oils.

The wide application of the Stansiphon is

apparent especially in chemical laboratories, drug stores, manufacturing and other establishments where liquids and various solutions are in constant use. In transferring corrosive poisons or valuable liquids it obviates liability to accident or waste. It should also have a wide application in the filling and emptying of all sizes of storage-battery jars. It is at present being used for siphoning beer from kegs and wine from barrels. When a solution is to be kept "on tap" for instant use a stopcock may be provided. These siphons in addition to glass are being made of brass, copper, zinc, lead, iron, hard rubber, etc.

When the self-starting attachment is sealed to a straight tube ending in a capillary, a very efficient intermittent Hero's Fountain is obtained, as shown in Fig. 2.

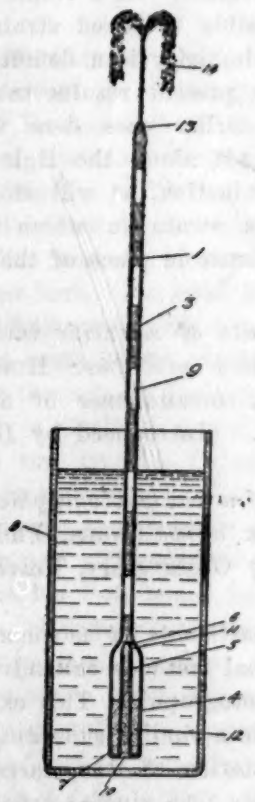

FIG. 2.

Application for patent rights has been made in the name of the inventor, Gustavus A. Storm, but all rights, title and interest in the same has been assigned to the Standard Scientific Company of New York.

P. B. PERKINS
BROWN UNIVERSITY

THE AMERICAN PHILOSOPHICAL SOCIETY

AT the annual general meeting of the society held in Philadelphia from April 13 to 15, the address of welcome was made by the President, Dr. W. W. Keen, who, with Vice-presidents W. B. Scott, George E. Hale and Albert A. Michelson, presided. This meeting is a notable event among scholars and over forty papers were presented in the sciences and in the humanities. The national crisis also received some attention, Dr. M. T. Bogert, of Columbia University, outlining the work chemists may do to aid the National Research Council in the solution of certain war problems. Proper insignia to identify "members of the industrial army" so they may not be called slackers was urged. Attention was called to England's sad mistake in permitting general enlistment for "the front" when in many cases men with special ability could have been of so much more value using their brains in the laboratory. A well-trained industrial army is just as important as the army of fighters. The program with a number of abstracts follows.

APRIL 12

William W. Keen, M.D., LL.D., President, in the chair

The trial of animals—a little known chapter of medieval jurisprudence: HAMPTON L. CARSON, LL.D., Philadelphia.

Medieval sermon-books and stories and their study since 1883: THOMAS FREDERICK CRANE, Ph.D., Litt.D., professor emeritus of the Romance languages and literature, Cornell University.

Some recent acquisitions to the Yale collection: ALBERT T. CLAY, LL.D., professor of Assyriology and Babylonian literature, Yale University.

Vision as a physical process: HERBERT E. IVES, Philadelphia. (Introduced by Dr. A. W. Goodspeed.)

The diagnostic method of training intelligence: an education for the fortunate few: LIGHTNER WITMER, Ph.D., director of the Laboratory of Psychology, University of Pennsylvania.

Historical notes on "the armament of Igor": J. DYNELEY PRINCE, Ph.D., professor of Slavonic languages, Columbia University.

A new translation of the Hebrew Bible: CYRUS ADLER, Ph.D., president of Dropsie College for Hebrew and Cognate Learning, Philadelphia.

APRIL 13

George Ellery Hale, Ph.D., Sc.D., LL.D., F.R.S., Vice-president, in the chair

Lighting in its relation to the eye: Clarence E. Ferree, Ph.D., professor of psychology, Bryn Mawr College. (Introduced by Dr. W. W. Keen.)

The work of which this paper is a brief outline was done under the auspices of the American Medical Association's subcommittee on the hygiene of the eye, of which Dr. William Campbell Posey, of this city, is chairman. The object of the work has been to compare the effect of different lighting conditions on the eye and to find the factors in a given lighting situation which cause the eye to lose in efficiency and to experience discomfort. In all, forty-two different lighting situations have been investigated, selected with special reference to the problem in hand. Also a number of miscellaneous experiments have been conducted pertaining to the hygienic employment of the eye. Tests were made to determine the eye's aggregate loss in functional activity and to analyze this effect. In all seven different types of tests were used.

Factors influencing the sex ratio in the domestic fowl: Raymond Pearl, Ph.D., biologist, Maine Agricultural Experiment Station, Orono, Maine.

The problem of the sex ratio is one of the most important of biology from the theoretical standpoint as well as from that of the practical breeder or farmer. The desire to control the proportions of the sexes produced is one which has excited mankind through the ages. Thanks primarily to the work of certain American biologists, notably Professor C. E. McClung, of the University of Pennsylvania, and Professor E. B. Wilson, of Columbia University, the key to the riddle of sex has at last been found. It is well known that in a wide range of animals there is a definite hereditary mechanism which irrevocably determines the sex of the individual. While it is true that a definite mechanism controls the determination of sex, yet there has appeared a great deal of evidence recently, of varying degrees of trustworthiness, that sex ratios may be experimentally modified and controlled. It is the purpose of this paper to examine the sex production question in the common fowl, and see to what conclusions it leads. In the present war conditions any information which would make it possible for the poultryman or farmer to produce a larger number of pullets to lay eggs without producing so many cockerels to eat up costly food, would be of very great value. This study, which is based on eight years' experiments, and over 22,000 individuals, demonstrates first that the determination of sex in poultry is primarily a matter of a definite, hereditary mechanism, just as it is in insects and other forms which have been studied. At the same time, it is demonstrated that under certain physiological circumstances the operation of this mechanism may be modified in such a way as to lead to the production of more females, in proportion to the number of males. The chief factor in bringing about the modification in the direction of a larger production of females is the fecundity or laying ability of the hens used as breeders. The larger the number of eggs which a hen lays before being put into the breeding pen, the larger will be the proportion of females and the smaller the proportion of males produced by her eggs. Some years ago it was shown by the speaker that the ability to lay eggs (fecundity) in poultry is a matter of definite Mendelian inheritance. As a result of this knowledge, it is possible to breed strains of hens in which high productivity is a definitely fixed characteristic. The present results taken in connection with the earlier ones show that when the poultryman breeds along the right lines for increased egg production, he will at the same time be producing a strain in which profit making pullets preponderate in place of the less profitable cockerels.

Significant results of scientific investigations applied to fishery problems: Hugh M. Smith, M.D., LL.D., commissioner of fisheries, Washington, D. C. (Introduced by Dr. Clarence E. McClung.)

A description of a new photographic transit instrument: Frank Schlesinger, Ph.D., director of the Allegheny Observatory, University of Pittsburgh.

In many departments of astronomy it has been found that visual methods can advantageously be replaced by photographic. This experiment is an attempt to make a similar substitution in the case of the determination of star places. The experiment is a timely one, since astronomers are confronted with the necessity for observing the places of many stars, this necessity arising out of the recent striking developments in the matter of star-streaming.

Probable masses of comets: Henry Norris Russell, Ph.D., professor of astronomy, Princeton University.

The relationship of stellar motions to absolute magnitudes: Walter S. Adams, A.M., Sc.D., assist-

ant director of Mt. Wilson Solar Observatory, Pasadena, Calif., and G. STRÖMBERG.

The spectroscopic method of deriving the absolute magnitudes of stars and a new formula connecting parallax and proper motion have been utilized to study the relationship between the motions of stars and their true or absolute magnitudes. About one thousand stars have been used in the investigation. The results establish almost certainly a definite increase of velocity with decrease in brightness. In radial velocity this is of the order of 1.5 kilometers for each magnitude for stars of the F, G, K and M types of spectrum. This is to be interpreted, probably in part at least, as an effect of mass: that is, the smaller stars move more rapidly than the larger stars. This increase of velocity with decrease in brightness is found to persist among the groups of stars arranged according to their distance from the sun. Accordingly the evidence does not indicate that the nearer stars are moving more rapidly than the distant stars.

Nebulæ: V. M. SLIPHER, Ph.D., director of the Lowell Observatory, Flagstaff, Arizona. (Introduced by Professor C. L. Doolittle.)

Early man in America: EDWIN SWIFT BALCH, A.B., Philadelphia.

The present status of knowledge about early man in America may be summed up as follows. Early man was here. He lived during at least a part of the Pleistocene period for tens of thousands of years south of the glacial moraines. He probably went through an Eolithic period and certainly through a Chelleen period in some places and therefore was truly a Paleolithic man. He may have made rudimentary fine art. Paleolithic American man was the ancestor of the Neolithic historic Indian and although less advanced in culture much like his descendant in anthropological characteristics. Whether he was an autochthone in America or whether he came from some other place and if so when, we do not as yet know positively, although his affiliations seem to be to the west. And it is to four men above all others that we owe our knowledge: Abbott, the discoverer of paleolithic implements and horizons; Volk, the corroborator; Lund, the first finder of probably Paleolithic bones, and Winchell, the investigator of patination.

The influence of the admixture of present immigrant races upon the more original stock: CHARLES B. DAVENPORT, S.B., Ph.D., director, Station for Experiment Evolution, Cold Spring Harbor, Long Island.

A new Babylonian account of the creation of man: GEORGE A. BARTON, Ph.D., LL.D., professor of biblical literature, Bryn Mawr College.

The waters of death: PAUL HAUPT, professor of Semitic philology, Johns Hopkins University.

APRIL 13

Albert A. Michelson, Ph.D., Sc.D., LL.D., F.R.S., Vice-president, in the Chair

Crushing of crystals: PERCY W. BRIDGMAN, assistant professor of physics, Harvard University.

Hollow cylinders cut from single crystals have been subjected to unique tests by applying large hydrostatic pressures to the external surface. The crushing strength under these conditions is much higher than that found by ordinary tests, and the manner of failure is different. This has an interesting geological significance in suggesting that open cavities may persist in the earth's crust at greater depths than could be expected from the usual methods of measurement.

Structure of the spectra of the phosphorescent sulphides (describing measurements by Drs. H. E. Howe, H. L. Howes and Percy Hodge): EDWARD L. NICHOLS, Ph.D., D.Sc., LL.D., professor of physics, Cornell University.

The Corbino effect in liquid mercury: EDWIN PLIMPTON ADAMS, Ph.D., professor of physics, Princeton University.

Spontaneous generation of heat in recently hardened steel: CHARLES FRANCIS BRUSH, Ph.D., Sc.D., LL.D., Cleveland.

I., Condensation and evaporation of metal films; II., The minimum potential for excitation of the "D" lines of sodium: ROBERT WILLIAMS WOOD, A.B., LL.D., professor of experimental physics, Johns Hopkins University.

Growth and imbibition: D. T. MACDOUGAL, Ph.D., LL.D., director of department of botanical research, Carnegie Institution of Washington, and H. A. SPOEHR.

The mechanism of overgrowth in plants: ERWIN F. SMITH, B.S., Sc.D., Bureau of Plant Industry, Department of Agriculture, Washington, D. C.

The behavior of self-sterile plants: EDWARD M. EAST, Ph.D., professor of experimental plant morphology, Harvard University.

There are really two problems connected with the inheritance of self-sterility in plants. One is the relation between self-sterile and self-fertile plants, the other is the behavior of self-sterile

plants when crossed together. They should not be confused. The *Nicotiana* self-fertility is completely dominant over self-sterility. Either of the self-sterile species *Nicotiana alata* or *Nicotiana forgetiana* may be crossed with the self-fertile species *Nicotiana langsdorffii*. The result in each case is an F_1 generation that is completely self-fertile. The F_2 plants show the usual monohybrid ratio of 3 self-fertile to 1 self-sterile. Given the basic factor for self-sterility in the homozygous condition as in the case in *Nicotiana forgetiana* and *Nicotiana alata*, two plants may be either *cross-fertile* or *cross-sterile* with each other. Reciprocal crosses always give the same result. Thus the character behaves as if it were sporophytic rather than gametic. In other words, the constitution of the mother plants and not the constitution of the gametes which they produce determines whether a combination shall be fertile or sterile. This fact indicates very strongly that gametes have no other function than fusion with their complements, that the potential characters which they carry are wholly latent until the development of the zygote begins. The cross-sterility shown is of such a nature that if plant A is sterile with plants B and C, plant B must be sterile with plant C. Generalizing upon the basis of the behavior of self-sterile plants in intercrosses one may say that a self-sterile population consists of a small number of groups of plants each plant being cross-sterile with all plants belonging to the same group and cross-fertile with all plants of all other groups. These facts naturally lead to the conclusions that the behavior of self-sterile plants in inter-crosses is regulated by several transmissible factors all of which are distinct from the single basic factor for self-sterility and which presumably may be carried by self-sterile plants. A plant homozygous for self-sterility can neither be fertilized by its own gametes nor by the gametes of any other self-sterile plant of like constitution as regards these regulation factors, but any two plants differing in these regulatory factors are cross-fertile.

Twin hybrids from Œnothera lamarckiana and franciscana when crossed with Œnothera pycnocarpa: George F. Atkinson, head of the department of botany, Cornell University.

Œnothera lamarckiana × *Œ. pycnocarpa.* There is a splitting in the F_1 with production of twin hybrids. One of the twins (*pycnocarpa* type) has rosette leaves narrow and deeply cut over the basal half as in *Œ. pycnocarpa,* but the leaves are strongly crinkled as in *Œ. lamarckiana.* The other twin (*lamarckiana* type) has rosette leaves, narrow furrowed, not crinkled as in *Œ. pycnocarpa,* but with plain edge as in *Œ. lamarckiana.* The rosettes of the *pycnocarpa* type strongly resemble those of *Œ. pycnocarpa* because of narrowness and cutness, while at the same time they resemble *Œ. lamarckiana* in convexity and crinkledness. The general appearance of the rosettes of the *lamarckiana* type suggests neither parent, since the factors selected represent the less striking character of each. These two twin types are fixed in the first generation, since they are repeated in the F_2 and probably in the following generations in accord with the usual behavior of twin hybrids determined by de Vries. The progeny is remarkably uniform, in that respect following the feature of uniformity in the progeny of the parents, except for an occasional mutant from the *pycnocarpa* type. This mutation factor is probably inherited from *lamarckiana. Œnothera franciscana* × *Œ. pycnocarpa.* There is a splitting in the F_1 with production of twin hybrids. One of the twin hybrids (*pycnocarpa* type) has rosette leaves with the narrowness and cutness of *Œ. pycnocarpa,* but otherwise modified by *Œ. franciscana.* The other twin has rosettes very similar to those of *Œ. franciscana,* somewhat modified by *Œ. pycnocarpa,* and showing considerable fluctuating variations, parallel with those of *Œ. franciscana.* In the F_2 generation there is a one-sided splitting similar to that which occurs in the F_2 of twins from *Œ. hookeri* × *Œ. lamarckiana* described by de Vries. The *pycnocarpa* type twin has a hybrid constitution and in the F_1 splits into two types, the *pycnocarpa* type and the *franciscana* type, the latter presenting fluctuating variations parallel with those in the parent *franciscana.* The other twin (*franciscana* type) is fixed in the F_1 since it repeats itself in the F_2 and probably in the succeeding generations, but it presents the fluctuating variations characteristic of the parent *franciscana.* The *franciscana* twin probably carries the *pycnocarpa* factors also, but in a subordinate or permanently latent condition. If so, it is a physiological homozygote. If it is possible to introduce a splitting factor into the *franciscana* twin by an appropriate cross, and cause the *pycnocarpa* character to reappear in some of the progeny, the fundamental heterozygotic constitution of the *franciscana* twin would be demonstrated.

Arthur W. Goodspeed,
Secretary

(*To be continued*)